

ANALYSIS OF COLLEMBOLAN COMMUNITIES IN HIGH ENDEMISM AREAS OF ALGARVE WITH PARTICULAR EMPHASIS TO ENDEMIC OR RARE SPECIES

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The authors studied the Collembola populations from High Endemism Areas (HEA) in Algarve in order to look for endemic or rare species and getting information on the origin and maintenance of endemism in this region. Here, five well delimited ecological areas have revealed good examples of endemisms mainly concerning Phanerogames but also several Arthropod groups. The overall analysis of the results reflects a distinguished separation of three groups of sites among the studied areas: the biotopes of Serra de Monchique, coastal "wet" biotopes (salt-marshes and dunes) and other "dry" coastal and inland sites (Sagres, Pinewood and Barrocal sites). In these areas we have found fifteen endemic Collembolan species and twenty three species not yet referred to our country or to the Iberian Peninsula, and also endemic or rare species of Isopoda, Pseudoscorpionida, Pauropoda and Staphylinidae, which contribute to enhance the real biological value of them in terms of biodiversity conservation.

Key words - Collembola, High Endemism Areas, endemic species, Algarve.

Gama, M.M., Sousa, J. P., Seabra, C. & Barrocas, H. (1998). Análise das comunidades de colêmbolos em Áreas de Elevado Endemismo do Algarve com particular atenção para as espécies endémicas e raras. *Revista Biol. (Lisboa)* 16: 67-86.

Os autores estudaram populações de Colêmbolos provenientes de Áreas de Elevado Endemismo no Algarve, a fim de investigar quais as espécies endémicas ou raras aí existentes e obter informações sobre a origem e manutenção dos endemismos nesta região. Aqui, cinco áreas ecológicas bem delimitadas revelaram bons exemplos de endemismos, principalmente no que respeita às Fanerogâmicas mas também a vários grupos de Artrópodes. A análise global dos resultados reflecte uma separação nítida de três grupos de biótopos nas áreas estudadas: os biótopos da Serra de Monchique, os biótopos costeiros "húmidos" (dunas e sapais) e os biótopos costeiros "secos" mais os biótopos do interior (Sagres, pinhais da Ria Formosa e Barrocal). Nestas áreas foram amostradas 15 espécies endémicas de Colêmbolos e 23 espécies ainda não citadas para Portugal ou para a Península Ibérica, além de espécies raras ou endémicas de Isópodes, Pseudoscorpíões, Paurópodes e Estafilínídeos, o que

contribui para realçar o valor biológico destas áreas em termos de conservação da biodiversidade.

Palavras Chave - Colêmbolos, Áreas de elevado endemismo, Espécies endémicas, Algarve.

INTRODUCTION

Conservation biology has emerged during the last decades as a major concept addressing the drastic loss of biological diversity throughout the world. Both scientists and general public have realized that we are living in a time of unprecedented extinction of biological communities, caused principally by habitat destruction stemming from human activities (PRIMACK, 1993).

In this context it is absolutely necessary to preserve and restore the habitats where species exist, with particular attention to endemic biota, which represent the most valuable and vulnerable component of edaphic communities (DEHARVENG, 1996).

Algarve, the Southernmost province of Portugal, is a special hotspot of biodiversity in the Iberian Peninsula, where several endemic species of flowering plants (ROCHA AFONSO, 1991) and Arthropods [(Thysanura (MENDES, 1985, 1992) Coleoptera Cicindelidae (HORN, 1937, SERRANO, 1988, 1995) and Homoptera Cicadoidea Tibicinidae (BOULARD, 1982, QUARTAU, 1995)] have been pointed out.

In spite of its relatively small area, this region offers a wide variety of soil diversity which allows to distinguish five well delimited ecological areas: Península de Sagres, Serra de Monchique, Barrocal, Parque Natural da Ria Formosa and Reserva Natural do Sapal de Castro Marim. We studied the Collembola communities from these areas with the aim to search for endemic or rare species and getting information on the origin and maintenance of endemism in this province.

This research is integrated in an EU program (1995-1997) entitled "High Endemism Areas,

Endemic Biota and the Conservation of Biodiversity in Western Europe".

MATERIAL AND METHODS

1. Study sites

Five areas representing the major landscape units in the Algarve province, and chosen by the presence of several species of plants and insects endemic to this region, have been sampled (Fig. 1).

In Serra de Monchique, Barrocal and Ria Formosa we considered several biotopes (some of them, sampled in different sites), whereas in Península de Sagres and Castro Marim only one biotope was considered.

1.1. Península de Sagres (designated by Sagres): it is a calcareous dolomitic region in the South-west extreme of Algarve, with cliffs ranging from 40 m high (Ponta de Sagres) to 70 m high (Cabo de S. Vicente). In terms of vegetation cover, this area presented shrub and herbaceous layers dominated by *Cistus ladanifer* L., *Thymus camphoratus* Hoffmanns & Link, an endemic species in southwestern Algarve, *Armeria pungens* (Link) Hoffmanns & Link and *Carpobrotus edulis* (L.) N.E. Br.

1.2. Serra de Monchique: the upper half of this mountain is predominantly syenitic, including Foia (902 m high), whereas the lower zone has a schistose nature. In this massif there are quite rare species of Phanerogames such as *Rhododendron ponticum* L. ssp. *baeticum* (Boiss. & Reuter) Hand.-Mazz. ("Iberian Rose Bay"), a relictual endemic restricted to a few sites of Southern Iberian Peninsula. Another important species appearing above 400 m of altitude is the Monchique oak, *Quercus canariensis* Willd., which presents a very

restricted occurrence both in Portugal and in Spain, being Serra de Monchique its exclusive area in Portugal. This tree appears nowadays only in small and scattered clumps (ROCHA AFONSO, 1991) or as individual specimens.

The sampled biotopes were: *Rhododendron ponticum baeticum* (designated Rhododendron), *Quercus canariensis* (designated Q. canariensis), *Quercus suber* (two sites, designated by Q. suber I

and II) and *Eucalyptus* sp. (three sites, designated by Eucalyptus I, II and III). Almost all sites (with the exception of Q. suber II) presented shrub and herbaceous layers composed mainly of *Pteridium aquilinum* (L.) Kuhn, *Cistus* spp., *Erica* spp. and *Viburnum tinus* L. (on oak and eucalyptus sites). All eucalyptus sites were in second rotation and presented a large accumulation of leaves and bark in the soil surface.

Study areas and sampling sites

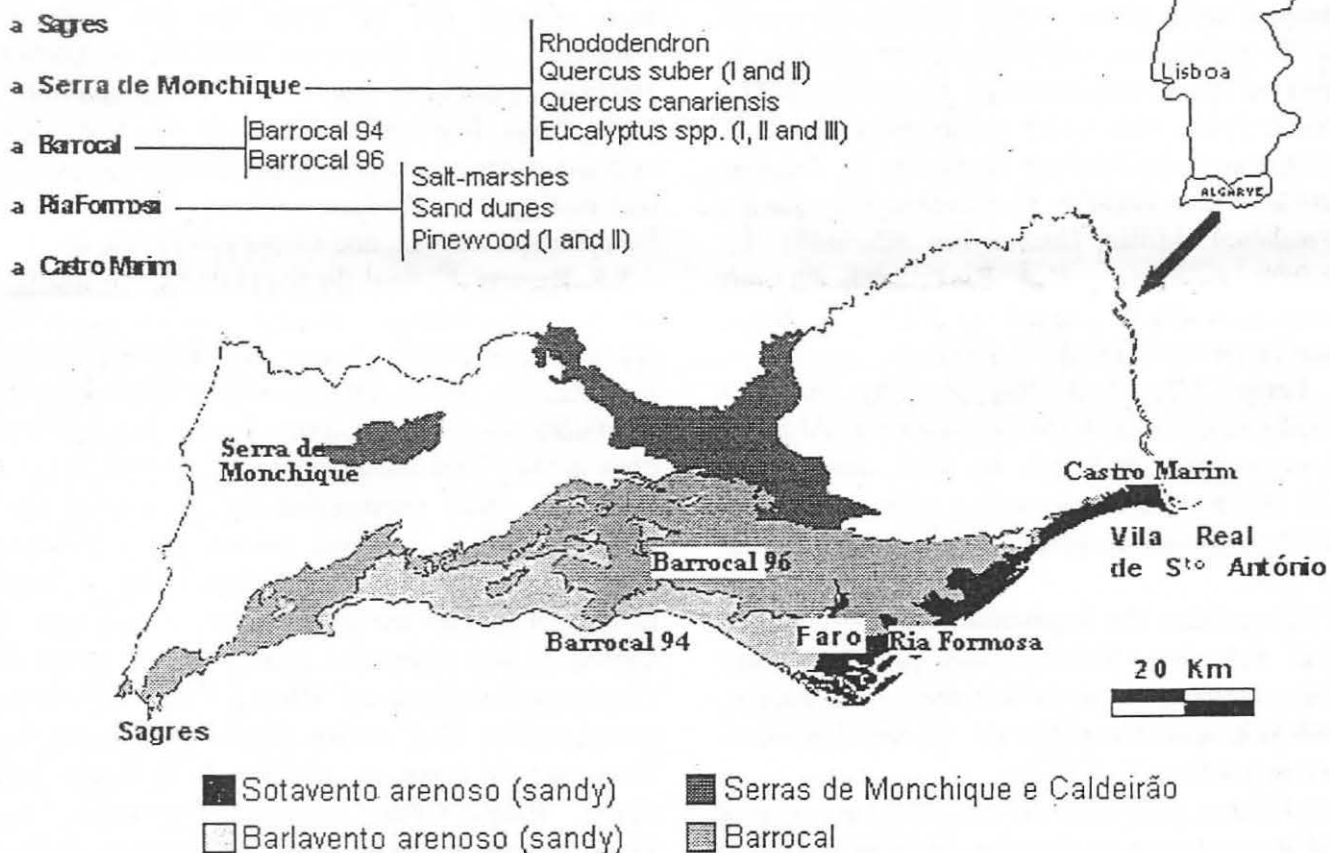


Fig. 1 - High Endemism Areas (HEA) in Algarve and sampling sites.

1.3. Barrocal: this region corresponds to a calcareous platform, bordered at the Southern littoral by the sandy zone of the Barlavento and the Sotavento. Sampling was done in Carvoeiro, near Farol de Alanzina, and in a place located between the villages of Alte and Salir (see Fig. 1):

- In the first biotope (referred as Barrocal 94) there was a shrub and herbaceous layer composed mainly of *Pistacia lentiscus* L., in association with *Smilax aspera* L. and *Chamaerops humilis* L. (the dwarf fan palm) that is found frequently in the Barrocal (ROCHA AFONSO, 1991).

- In the second biotope (referred as Barrocal 96) the samples were taken mainly around *Ceratonia siliqua* L. (carob tree) one of the most characteristic trees of the Mediterranean region (ROCHA AFONSO, 1991) with a rich shrub and herbaceous layer constituted by *Pistacia lentiscus* L., *Daphne gnidium* L., *Cistus albidus* L., *C. monspeliensis* L., *Arum italicum* Miller, *Rosmarinus officinalis* L., *Asphodelus ramosus* (L.) Brot., and *Phlomis purpurea* L. which in Algarve is found only in the Barrocal (ROCHA AFONSO, 1991).

1.4. Parque Natural da Ria Formosa: this is a protected coastal area in the South-east of Algarve, which is partially occupied by sand dunes, salt-marshes and pine forest. Sampling in these biotopes was done at Quinta de Marim in May 1995 and in March 1996.

- In salt-marshes the vegetation was composed of *Spartina maritima*, *Sarcocornia perennis* ssp. *perennis*, *Halimione portulacoides* (L.) Aellen, *Mesembryanthemum nodiflorum* L. and *Limonias-trum monopetalum* (L.) Boiss.

- Sand dunes presented an abundant and diverse vegetation composed of *Spartina maritima* (Curtis) Fernald, *Juncus maritimus* Lam., *Suaeda albescens* Lázaro-Ibiza, *Suaeda vera* J. F. Gmelin, *Sarcocornia perennis* (Mill.) A. J. Scott ssp. *perennis*, *Paronychia argentea* Lam. and *Cistanche phelypaea* (L.) P. Coutinho, a beautiful plant with a yellow

corolla forming a broadly funnel-shaped and *Dittrichia viscosa* (L.) W. Greuter ssp. *revoluta* (Hoffmanns & Link) P. Silva & Tutin, an endemic of sandy places in Algarve.

- In pine stands, constituted by *Pinus pinea* L. and *P. pinaster* Aiton, we sampled in two sites: (1) *Pinus* I (Pinewood I) presented a shrub and herbaceous layer composed of *Euphorbia segetalis* L., *Raphanus raphanistrum* L., *Echium tuberculatum* Hoffgg. & Link, *Cistus salvifolius* L., *Arum italicum* Miller, *Oxalis pes-caprae* L., *Urginea maritima* (L.) Baker, *Halimium halimifolium* (L.) Willk., which is very common on littoral sands or in sandy places not far from the sea, both in Barlavento and in Sotavento (ROCHA AFONSO, 1991) and *Lavandula stoechas* L. var. *sampaiana*; (2) in *Pinus* II (Pinewood II) there was a less rich vegetation composed principally of *Linaria spartea* (L.) Hoffgg. & Link, *Linum bienne* Miller, *Rumex bucephalophorus* L., and *Cistus salvifolius* L.

1.5. Reserva Natural do Sapal de Castro Marim: this protected area of salt-marshes is located in the South-East corner of Algarve, delimited at South by Vila Real de Santo António and at South-East by the Guadiana river. Sampling in this biotope was done in May 1995 (designated by C. Marim 95) and in March 1996 (designated by C. Marim 96). During this last sampling period, the vegetation cover was abundant and diverse, with a large number of species not characteristic of this type of habitat. It was composed mainly of specimens of *Chamaemelum fuscum* (Brot.) Vasc., *Halimione portulacoides* (L.), Aellen, *Oxalis pes-caprae* L., *Sarcocornia perennis* (Mill.) A. J. Scott ssp. *alpini* (Lag.) Castr., *Plantago coronopus* L., *Cistus monspeliensis* L., *Lythrum junceum* Banks & Solander, *Juncus buffonius* L., *Rumex bucephalophorus* L. ssp. *gallicus*, *Triglochin maritima* L., *Silene gallica* L., *Cotula coronopifolia* L., *Anagallis arvensis* L., *Erodium botrys* (Cav.) Bertol., *Amophila arenaria* (L.) Link ssp. *arundinacea* H.

Lindb., *Limoniastrum monopetalum* (L.) Boiss. which is only found, in Portugal, in the Algarvian salt-marshes of Barlavento and Sotavento (ROCHA AFONSO, 1991), *Polygonum equisetiforme* Sibth & Sm., *Limonium ferulaceum* (L.) Chaz. and *Suaeda vera* J. F. Gmelin.

2. Sampling and soil characterization

Sampling was done in several visits to the Algarve region between 1994 and 1996. In each biotope several points (7-29) were randomly selected and at each point we took two samples of 250 cm³ each (one in the organic horizon and another in the mineral horizon). On those biotopes where the litter was not present we took only one sample of 500 cm³.

After faunal extraction (Berlese-Tullgren funnels), all air-dried samples were used for physical and chemical characterization: pH was measured in water (1/6 v:v) at 20°C; water content was measured according to DEWIS & FREITAS (1984) and was expressed in terms of percentage of water in relation to dry weight at 105°C; organic matter content was expressed as Ash Free Dry Weight; carbon and nitrogen contents were measured by Anne's and Kjeldahl's methods respectively (DEWIS & FREITAS, 1984). Physical and chemical characterization is represented in Fig. 2. Due to non significant differences among measured parameters at the different sites of Pine wood, C. Marim, Q. suber and Eucalyptus, the values were pooled.

3. Data analysis

Differences in community composition of each biotope were evaluated using both diversity and multivariate analysis. Prior to analysis, in order to establish comparisons between sites, we have pooled the data on those points where two samples of 250cm³ were taken, making an equal sample size of 500cm³ for all sites.

In the first level of analysis the indices of diversity (Shannon-Weaver), evenness and species richness (Margalef) were calculated for each site (MAGURRAN, 1991).

In the second level of data treatment an agglomerative hierarchical clustering method was applied to the two similarity matrices (resulting from the overall data matrix - 16 sites vs. 174 taxa) obtained from the Bray-Curtis similarity coefficient. From here resulted a diagram in Q mode (relations among sites) and another in R mode (relations among taxa). Prior to the analysis, and in order to correct for differences in the number of samples taken at each site, the values were expressed in terms of mean number of individuals per volume unit.

RESULTS AND DISCUSSION

A total of 30203 specimens, distributed by 174 taxa, were identified in the five sampling areas.

Rhododendron supported the highest abundance of all sites, with a mean number of 504.1 individuals/sampling unit (Tab. I). In terms of abundance, there was a gradient from the other inland biotopes to the coastal sites (C. Marim 95 and 96; Salt-Marshes and even Sagres). The mean number of taxa followed more or less a similar pattern. This gradient of values seems to be related with the soil physical and chemical characterization (Fig. 2); an higher number of individuals and taxa per sample occurred on sites with higher values of water, organic matter, carbon and nitrogen contents in the mineral horizon. In effect higher abundances and species richness of Collembola are usually associated with humid environments and sites with higher organic matter content (RUSEK, 1989).

The gradient in species diversity was different. Although Q. canariensis had the highest value, the coastal biotopes (Sagres and sites from Ria Formosa) had, in general, higher values of species diversity. The exception is the salt-marsh biotope

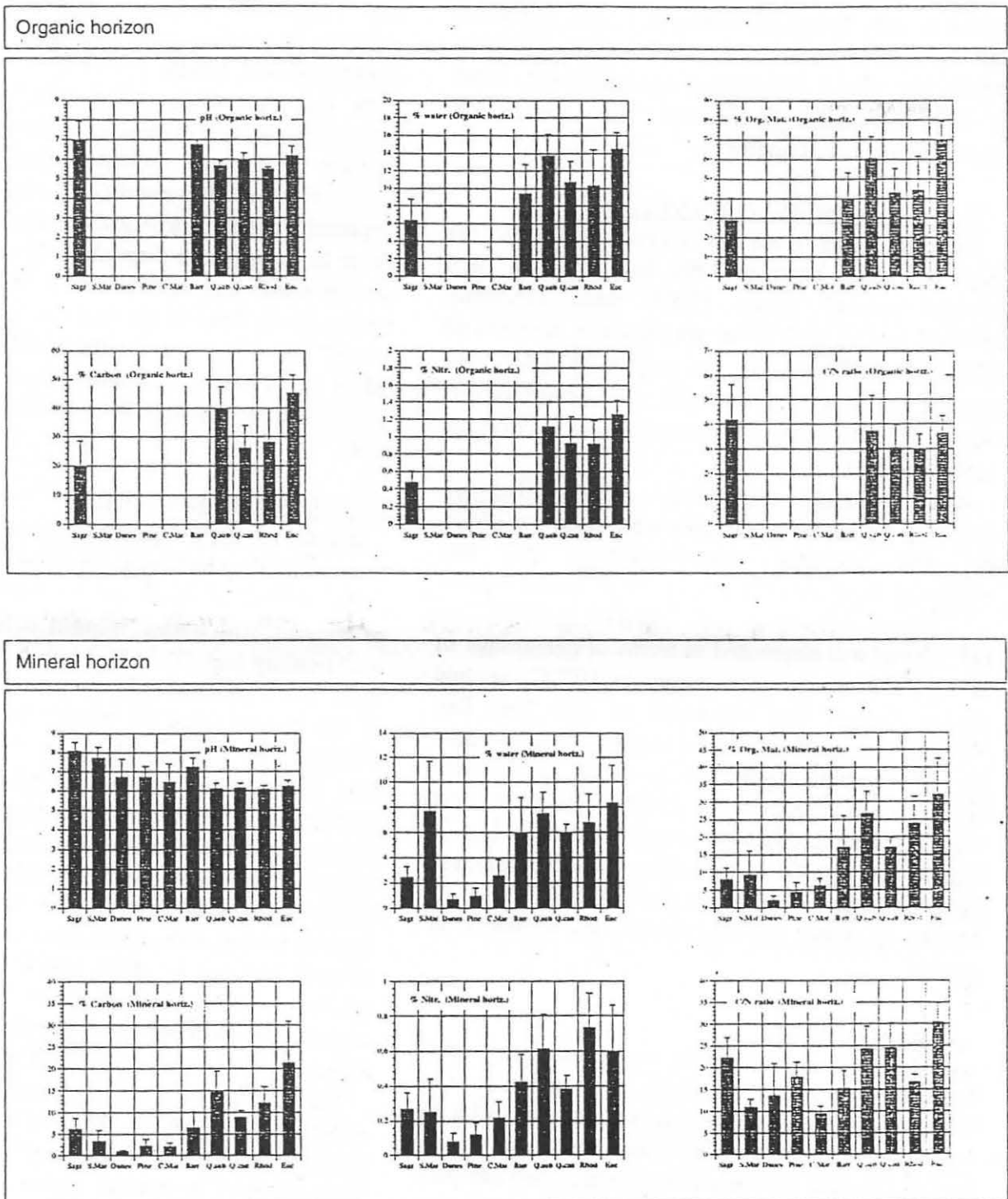


Fig. 2 - Physical and chemical parameters (average \pm SD) in sampling biotopes.

from C. Marim; the low diversity values obtained on both sampling periods are due either to the low number of taxa (in the case of C. Marim 95) or to the decrease in evenness (C. Marim 96). Inside Serra de Monchique, the diversity in Eucalyptus III seems to misfit the general pattern, e.g. higher diversity for the allochthonous biotopes. The reason for this is related to the increase in evenness (when compared to the other eucalyptus sites) and not to a difference in species number. In general terms, the diversity values in all sites seems to be more influenced by the distribution of individuals among the different taxa rather than species number.

A parallel between species diversity and species richness values is not so linear. Richness is strongly dependent on number of taxa identified at each site, therefore being related to the number of samples taken. Even so, we can denote that besides Sagres, the highest values of species richness occurred again in the inland biotopes (with the exception of eucalyptus sites in Serra de Monchique). This may be again related with the biotope characterization mentioned before.

The phenogram of Q mode analysis (Fig. 3) points out a clear separation of three groups. The first group is represented by Serra de Monchique where Eucalyptus I and Eucalyptus II are separated from Eucalyptus III, which is more closely related to the other biotopes, especially to Q. canariensis and Rhododendron. This fact may be explained by the relative abundance of *Ceratophysella gibbosa* and *Pseudachorudina bougisi* in the three sites and of *Proisotoma minuta* in Eucalyptus III and *Quercus canariensis*. The association between Eucalyptus I and Eucalyptus II may be related mainly to the high abundance of *Xenylla brevisimilis mediterranea* in these stands.

In the second group, composed of Pinewoods I and II, Sagres and Barrocal 94 and 96, there is an association between the Pinewood sites and among Sagres and Barrocal 94 and 96. The great abun-

dance of *X. brevisimilis mediterranea* in Sagres, Barrocal 94 and Barrocal 96 may explain the similarity among these sites. However, the degree of correlation between Sagres and Barrocal 94 is higher than between Sagres and Barrocal 96, which could be mainly due to the presence of *Cryptopygus debilis*, significantly abundant in the first two sites.

The third group includes the wet coastal habitats in which salt-marshes is more closely associated with C. Marim 95 than with C. Marim 96. This association may be related to the relative abundance of *Folsomia quadrioculata* in both biotopes. It is interesting to denote in dunes and in C. Marim 95 sites the exclusive presence of *Paraxenylla affiniformis*, *Archisotoma interstitialis* and *Axelsonia littoralis*, characteristic species of these habitats, and in dunes and salt-marshes the presence of *Friezea acuminata*, also characteristic of the maritime border.

The separation among the biotopes is much more evident in the phenogram of the R analysis (Fig. 4). The first group designed by salt-marshes comprehends nine taxa exclusive or dominating in this biotope, in spite of the fact that the first three species (*Ceratophysella armata*, *Folsomia quadrioculata*, and *Ceratophysella engadinensis*) appear in other biotopes (Tab. I). Among the species of this cluster we can highlight *Proisotoma ripicola* which occurs normally in sandy soils near water margins and *Mesaphorura hylophila*, also found in Sagres, which is cited for the first time to Portugal (Tab. III).

The second group corresponds to the sand dunes biotope and is composed of fourteen species occurring mainly in this site, most of them being characteristic of littoral and lagoon-side habitats: *Archisotoma interstitialis* (also found in C. Marim 95), *Friezea acuminata* (also found in salt-marshes), *Scaphaphorura arenaria* (also found in Sagres), *Paraxenylla affiniformis*, *Proisotoma schoetti* (also found in salt-marshes and C. Marim

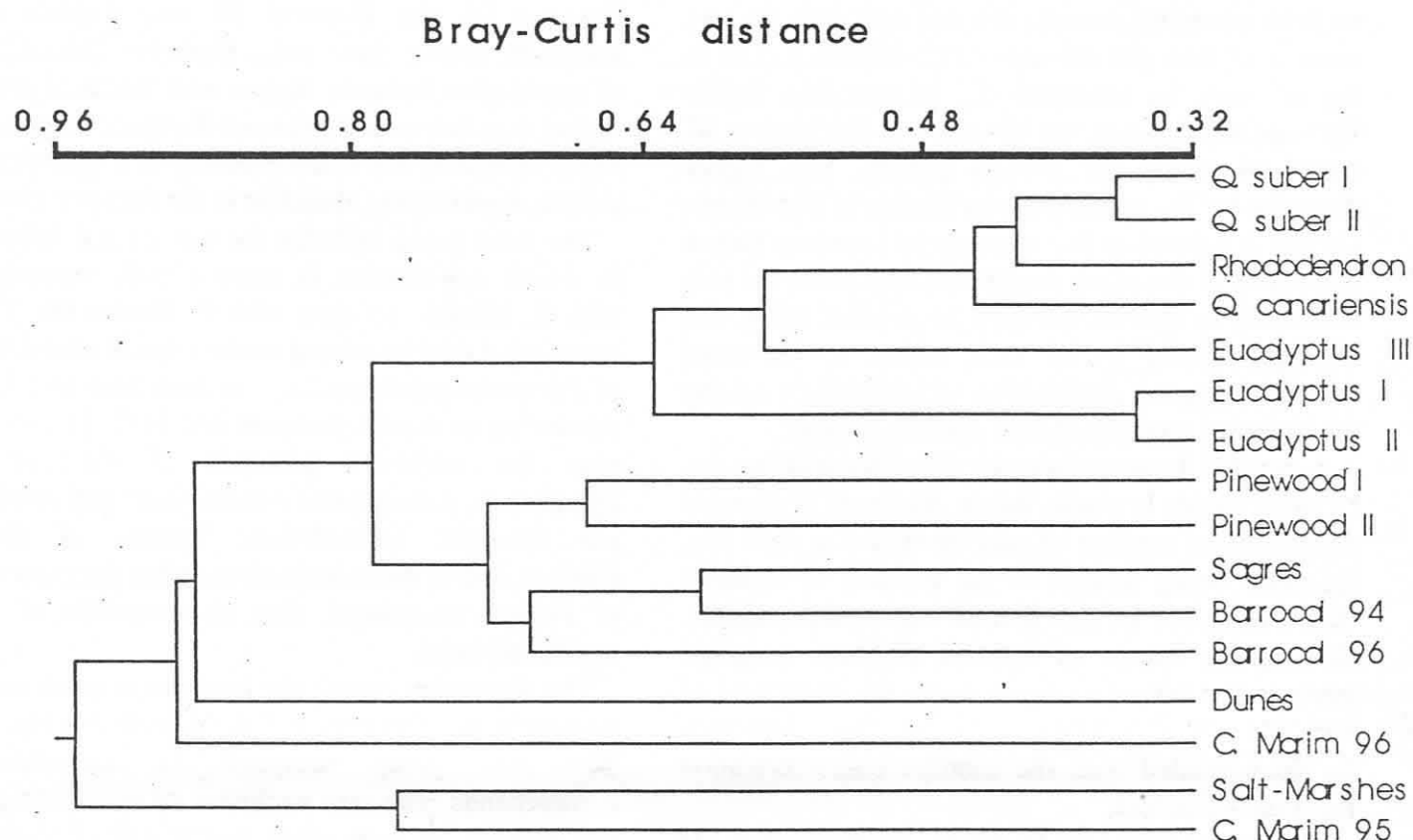


Fig. 3 - Diagram resulting from an agglomerative analysis (Q mode) on the overall data matrix. Similarities were calculated over average abundances, based on Bray-Curtis coefficient.

96), *Isotoma maritima meridionalis* and *Sminthurides malmgreni*. The first three species are for the first time cited to Portugal (Tab. III). The presence of *Paraxenylla affinis* here and in C. Marim 95 contributes to increase the area of this species distribution which some years ago was restricted to Balkans.

The next group of species, composed of *Anurida maritima*, *Bourletiella* sp., *Entomobrya* sp. and *Axelsonia littoralis* show character of exclusivity for C. Marim 95, only the last species appearing also in dunes, but with a poor abundance.

The fourth group (sixteen taxa) represents another cluster occurring almost exclusively in Sagres peninsula. Among the species found here

Entomobrya handschini (also found in Barrocal 96), *Mesaphorura florum*, an Iberian endemic, (also found in C. Marim 95) and *Arrhopalites microphthalmus* are, for the first time, recorded for the Portuguese fauna (Tab. III).

The large group appearing next (extending from *Ceratophysella gibbosa* - Cgi - to *Pseudosinella* sp. - Pse 6 - and divided into several sub-groups) represents those taxa associated with the biotopes from Serra de Monchique (Fig. 4).

The first sub-group (designated by General group) is composed mainly by those taxa that are also well represented in other biotopes, showing either: (1) higher abundance - *Pseudachorudina bougisi*, *Isotomiella minor*, *Parisotoma notabilis*

Tab. I - Abundance of Collembola species in the five areas studied. Also diversity indicators on all biotopes.

Taxa	Serra de Monchique										Ria Formosa					
	Sagres	Rhod.	Q.can.	Q.suber I	Q.suber II	Euc. I	Euc. II	Euc. III	Barr. 94	Barr. 96	Salt-marshes	Dunes	Pine I	Pine II	C.Mar. 95	C.Mar. 96
Car <i>Ceratophysella armata</i> (Nicolet, 1841)	9									15	24	10	4	1		
Cen <i>Ceratophysella engadinensis</i> Gisin, 1949	4										11				8	
Cgi <i>Ceratophysella gibbosa</i> (Bagnall, 1940)	23	71	90	62	57	2	2	70	62	31			94	1		
Cte <i>Ceratophysella tergilobata</i> Cassagnau, 1954											1					
Cte <i>Hypogastrura affinis</i> Cassagnau, 1954										12						11
Hve <i>Hypogastrura vernalis</i> (Carl, 1901)									4							
Mmi <i>Microgastrura minutissima</i> (Mills, 1934)	1	3								14						
Mse <i>Microgastrura sensiliata</i> (Jordana, 1981)				6	1			5				1				
Mic1 <i>Microgastrura</i> juv. (Salt-marshes)											4					
Mic2 <i>Microgastrura</i> juv. (Pinewood I)													5			
Paf <i>Paraxenylla affinisformis</i> (Stach, 1929)												96			16	
Win <i>Willemia intermedia</i> Mills, 1934		1						1								
Xbe <i>Xenylla brevisimilis mediterranea</i> Gama, 1964	339	1		58	1	249	496		430	463		350		1		
Xma <i>Xenylla maritima</i> Tullberg, 1869	8								137			130			4	2
Xsc <i>Xenylla schillei</i> Börner, 1903		4	2													
Xar <i>Xenylloides armatus</i> Axelson, 1903														1		
Xoc <i>Xenyllogastrura octoculata</i> (Steiner, 1955)	3								162			38	411	70		7
Bcu <i>Brachystomella curvula</i> Gisin, 1948														10		
Bpa <i>Brachystomella parvula</i> (Schäffer, 1896)													5			6
Ama <i>Anurida maritima</i> (Guerin, 1838)															4	
Bau <i>Bilobella aurantiaca</i> (Caroli, 1912)	1	2	2	8	3	3	5	4		123			6	5		
Dat <i>Deutonympha atlantica</i> Deharveng, 1982		25	4	11	7	8	9	4								
Fac <i>Friezea acuminata</i> Denis, 1925											3	30				
Fde <i>Friezea pseudodecipiens</i> Arbacia & Jordana, 1997		80	6		59	1										
Fla <i>Friezea ladeiroi</i> Gama, 1959									1				16			31
Fmi <i>Friezea mirabilis</i> (Tullberg, 1871)									17	1		1				101
Fst <i>Friezea stuchi</i> Kseneman, 1936										15						
Gve <i>Gamachorutes verrucosus</i> Cassagnau, 1978										13			1			
Micr1 <i>Micranurida</i> (2+2 eyes) sp.1	9	1		12	13		3	9		2	9	1				
Micr2 <i>Micranurida</i> (2+2 eyes) sp. 2											4					
Nea <i>Neanura</i> sp. (Q.suber I)				3												
Pbo <i>Pseudachorudina bougisi</i> Delamare, 1951	3	270	290	56	63	1	45	85	80	349			1	5		1
Ppal <i>Pseudachorutes palmiensis</i> Börner, 1903	1		1				1	2		24						
Ppar <i>Pseudachorutes parvulus</i> Börner, 1901	2	1						11								
Psu <i>Pseudachorutes subcrassus</i> Tullberg, 1871			1	5						35						
Pse1 <i>Pseudachorutes</i> sp. (Pinewood I)													36			
Pse2 <i>Pseudachorutes</i> sp. (Sagres)	19															
Pse3 <i>Pseudachorutes</i> sp. (Barrocal 96)										9						

Tab. I - Abundance of Collembola species in the five areas studied. Also diversity indicators on all biotopes (cont.)

Taxa	Serra de Monchique										Ria Formosa					
	Sagres	Rhod.	Q.can.	Q.suber I	Q.suber II	Euc. I	Euc. II	Euc. III	Barr. 94	Barr. 96	Salt-marshes	Dunes	Pine I	Pine II	C.Mar. 95	C.Mar. 96
Fgi <i>Fissuraphorura gisini</i> (Selga, 1963)		7	1													
Mar <i>Mesaphorura arbei</i> Simón & Lucíañez, 1994			1	6	6		12					1				
Mco <i>Mesaphorura</i> sp. 1	5				1	1	1	1								
Mcr <i>Mesaphorura critica</i> Ellis, 1976					1		1	8								
Mfl <i>Mesaphorura floriae</i> Simón & Lucíañez, 1994	2														1	
Mhy <i>Mesaphorura hylophila</i> Rusek, 1982	2										4					
Mis <i>Mesaphorura</i> sp. 2	2		1	1	1	1	1	23								
Mkr <i>Mesaphorura krausbaueri</i> Börner, 1901	1															
Mma <i>Mesaphorura</i> sp. 3	8	1	1	4	4	2	8	11								
Mmac <i>Mesaphorura macrochaeta</i> Rusek, 1976	4	11	13	6	11	1		16				70				
Myo <i>Mesaphorura yosii</i> (Rusek, 1967)	1		2	2		7		11								
Mes1 <i>Mesaphorura</i> sp. (Dunes)												24				
Mes2 <i>Mesaphorura</i> sp. (Pinewood I)													40			
Mes3 <i>Mesaphorura</i> sp. (Pinewood II)														34		
Mes4 <i>Mesaphorura</i> sp. (C. Marim 96)																195
Mes5 <i>Mesaphorura</i> sp. (Barrocal 94)									1							
Mes6 <i>Mesaphorura</i> sp. (Barrocal 96)										222						
Maf <i>Metaphorura affinis</i> (Börner, 1903)									9	53				1		
Met <i>Metaphorura denisi</i> Simón, 1985										266						
Oci <i>Onychiurus circulans</i> Gisin, 1952					1											
Oin <i>Onychiurus insinuans</i> Gisin, 1952			52	11	8											
Ope <i>Onychiurus penetrans</i> Gisin, 1952								16								
Ops <i>Onychiurus pseudostachianus</i> Gisin, 1956			25													
Pca <i>Paratullbergia callipygos</i> (Börner, 1903)	1	2	3		3			2								
Par1 <i>Protaphorura armata</i> (Tullberg, 1869)						4	5		5	5						1
Par2 <i>Protaphorura</i> gr. <i>armata</i>										19						
Pfi <i>Protaphorura fimata</i> (Gisin, 1952)												68				
Pgis <i>Protaphorura gisini</i> (Haybach, 1960)										44				1		
Sar <i>Scaphaphorura arenaria</i> (Petersen, 1965)	13											22				
Squ <i>Stenaphorura quadrispinu</i> Börner, 1901	2															
Ain <i>Archisotoma interstitialis</i> Delamare, 1954												54			31	
Ali <i>Axelsonia littoralis</i> (Moniez, 1890)												1			4	
Cde <i>Cryptopygus debilis</i> (Cassagnau, 1959)	745	23	1		63		2		215	2				167		1
Cpo <i>Cryptopygus ponticus</i> (Stach, 1947)														6		
Csc <i>Cryptopygus scapelliferus</i> (Gisin, 1955)	1	14	26	27	227	1		16			3		53		2	
Csp <i>Cryptopygus sphagneticola</i> (Axelson, 1912)			3													
Cth <i>Cryptopygus thermophilus</i> (Axelson, 1900)	42	7	2		45	1	1		391	5321	3	1	133	16		729
Fca <i>Folsomia candida</i> Willem, 1902		6	581													
Fqu <i>Folsomia quadrioculata</i> (Tullberg, 1871)	4									2	55		2	4	97	1
Fse <i>Folsomia sexoculata</i> (Tullberg, 1871)	33	416	134	1233	1131	502	1136	45					2			

Tab. I - Abundance of Collembola species in the five areas studied. Also diversity indicators on all biotopes (cont.)

Taxa	Serra de Monchique										Ria Formosa					
	Sagres	Rhod.	Q. can.	Q. suber I	Q. suber II	Euc. I	Euc. II	Euc. III	Barr. 94	Barr. 96	Salt-marshes	Dunes	Pine I	Pine II	C. Mar. 95	C. Mar. 96
Bou4 <i>Bourletiella</i> sp. (Pinewood II)														31		
Bou5 <i>Bourletiella</i> sp. (Sagres)	2															
Bou6 <i>Bourletiella</i> sp. (C. Marim 95)															5	
Bou7 <i>Bourletiella</i> sp. 1 (C. Marim 96)																2
Bou8 <i>Bourletiella</i> sp. 2 (C. Marim 96)																1
Cbr <i>Capraínea bremondi</i> (Delamare & Bassot, 1957)			3	2						1				1		
Dic <i>Dicyrtoma</i> sp. (Barrocal 94)									2							
Dmi <i>Dicyrtomina minuta</i> (Linnaeus, 1767)									31	3						
Dor <i>Dicyrtomina ornata</i> (Nicolet, 1841)										4						
Llub <i>Lipothrix lubbocki</i> (Tullberg, 1872)	1	19	3	2	14				11	1						
Sma <i>Sminthurides malmgreni</i> (Tullberg, 1876)												3				
Spa <i>Sminthurides parvulus</i> (Krausbauer, 1898)		13		7							2	1				
Sau <i>Sminthurinus cf. aureus</i> (Lubbock, 1862)													5			
Sbi <i>Sminthurinus bimaculatus</i> (Axelson, 1902)	6	46		10	1					12						
Sdo <i>Sminthurinus domesticus</i> Gisin, 1963										1						
Sel <i>Sminthurinus elegans</i> (Fitch, 1863)	1															
Smu <i>Sminthurus cf. multipunctatus</i> Schäffer, 1896		1														
Smin1 <i>Sminthurus</i> sp. (C. Marim 96)																2
Smin2 <i>Sminthurus</i> sp. (Barrocal 94)									3							
Spu <i>Sphaeridia pumilis</i> Krausbauer, 1898	45	9	34	127	39				184	19		12	6	8		4
Shy <i>Stenacidia hystrix</i> (Börner, 1903)									4							
Sde <i>Stenognathellus denisi</i> Cassagnau, 1953			4	1	5											
Sjuv <i>Symphyleona juv.</i>	45	36	9	2	11				5	11	3		4	13		
Number of samples	20	7	8	5	4	4	4	4	9	20	9	10	5	3	29	22
Total abundance	1763	3529	2056	2106	1997	865	1902	486	1799	8865	188	1499	966	522	218	1442
Number of Taxa	57	45	46	41	37	21	23	25	30	49	20	29	29	27	13	31
Average abundance	88,2	504,1	257,0	421,2	499,3	216,3	475,5	121,5	199,9	443,3	20,9	149,9	193,2	174,0	7,52	65,6
Average number of Taxa	9,5	22,1	16,3	21,0	21,5	9,5	10,8	14,8	9,4	15,0	4,6	5,1	11,8	13,7	1,3	4,5
Diversity (H')	3,27	2,56	3,48	2,66	2,68	1,73	1,69	3,45	3,22	2,57	3,25	3,25	3,03	3,46	2,58	2,65
Evenness	0,56	0,47	0,63	0,49	0,52	0,39	0,38	0,74	0,66	0,46	0,75	0,67	0,62	0,73	0,69	0,53
Richness (D)	7,49	5,39	5,89	5,23	4,74	2,96	2,91	3,88	3,87	5,28	3,63	3,83	4,07	4,16	2,23	4,12

Tab. II - Portuguese endemic species or Iberian endemic species (*) from High Endemism Areas (HEA) in Algarve

	Sagres	Serra de Monchique				Ria Formosa		
		Rhododendron	<i>Q. canariensis</i>	<i>Q. suber</i> sites	Eucalyptus sites	Barrocal 96	Sand dunes	Pinewood sites
<i>Microgastrura sensiliata</i> Jordana, 1981 (*)				7	5		1	
<i>Deutonura atlantica</i> Deharveng, 1982		25	4	18	21			
<i>Gamachorutes verrucosus</i> Cassagnau, 1978 (*)						13		1
<i>Mesaphorura arbei</i> Simón & Lucianez, 1994 (*)			1	12	12		1	
<i>Mesaphorura floriae</i> Simón & Lucianez, 1994 (*)	2							1
<i>Mesaphorura</i> sp.1 (*)	5			1	3			
<i>Mesaphorura</i> sp.2	2		1	2	25			
<i>Mesaphorura</i> sp.3	8	1	1	8	21			
<i>Proisotoma coeca</i> Gama, 1961					2			
<i>Proisotoma gisini</i> Gama, 1964								8
<i>Lepidocyrtus lusitanicus</i> Gama, 1964 (*)		1	29	17	1		1	
<i>Lepidocyrtus tellecheae</i> Arbea & Jordana, 1990(*)		3						
<i>Friezea pseudodecipiens</i> Arbea & Jordana, 1997		80	6	59	1			
<i>Pseudosinella</i> sp.								2
<i>Troglopedetes cavernicola</i> Delamare, 1944						13		
<i>Willowsia</i> sp.		2				3		

and *Heteromurus major* (in Barrocal 1996), *Cryptopygus debilis* (in Pinewood II, Sagres and Barrocal 1994)¹ and *Cryptopygus thermophilus* (in Pinewood I, Castro Marim 1996, Barrocal 1994 and Barrocal 1996; or (2) the same degree of abundance (*Ceratophysella gibbosa*, *Sphaeridia pumilis* and *Xenylla brevisimilis mediterranea*).

The second subgroup (designated by Quercus sites+Rhododendron) is represented by taxa that occur mainly on these biotopes, being very sporadic in a few biotopes out of Serra de Monchique. Only

Bilobella aurantiaca is better represented in Barrocal 96 than in Serra de Monchique and *Mesaphorura macrochaeta* in dunes. Eight of these species show higher values of abundance in Rhododendron than in Quercus, being *Tetracanthella proxima* the best represented species with 2025 individuals. Also eight species are more densely represented in Quercus than in Rhododendron. Among these species five are more abundant in *Q. suber* (e.g., *Cryptopygus scapelliferus* - although this species is also well represented in Pinewood I) and three in *Q. canariensis* (mainly *Folsomia candida* with 581 individuals). *Onychiurus pseudostachianus* is exclusive of this oak site. Among the species of this subgroup we can denote *Deutonura atlantica* endemic to Portugal as well as *Mesaphorura* sp.3

¹ It is important to denote that the presence of this species, characteristic of mountain beech forest from Pyrenees, in several sites of Algarve, remains a puzzling question!

also probably endemic and three Iberian endemic species, *Mesaphorura arbei*, *Lepidocyrtus lusitanicus* and *Friesea pseudodecipiens* (Tab. II). This species and *Folsomides navacerradensis* are recorded for the first time to our country (Tab. III).

The seven species which compose the third subgroup appear in Eucalyptus sites, but are also represented in Quercus and very rarely in other biotopes. Among these species, *Pseudachorutes parvulus*, *Mesaphorura critica*, *M. sp.2* and *M. yosii* are dominating

Tab. III - Species from High Endemism Areas (HEA) in Algarve referred to Portugal or to the Iberian Peninsula (*) for the first time

	Serra de Monchique						Ria Formosa				
	Sagres	Rhododendron	<i>Q. canariensis</i>	<i>Q. suber</i> sites	Eucalyptus sites	Barrocal 94	Barrocal 96	Salt-marshes	Dunes	Pinewood sites	C. Marim
<i>Friesea acuminata</i> Denis, 1925 (*)								3	30		
<i>Friesea pseudodecipiens</i> Arbea & Jordana, 1997		80	6	59	1						
<i>Friesea stachi</i> Kseneman, 1936 (*)							15				
<i>Odontellina bisetosa</i> Selga, 1963											
<i>Microgastrura minutissima</i> (Mills, 1934)	1	3					14				
<i>Onychiurus penetrans</i> Gisin, 1952 (*)					16						
<i>Protaphorura fimata</i> (Gisin, 1952)									68		
<i>Fissuraphorura gisini</i> (Selga, 1963)		7	1								
<i>Mesaphorura critica</i> Ellis, 1976				1	9						
<i>Mesaphorura florum</i> Simón & Lucíañez, 1994	2										1
<i>Mesaphorura hylophila</i> Rusek, 1982	2							4			
<i>Metaphorura denisi</i> Simón, 1985							266				
<i>Scaphaphorura arenaria</i> Petersen, 1965	13								22		
<i>Archisotoma interstitialis</i> Delamare, 1954									54		31
<i>Cryptopygus debilis</i> (Cassagnau, 1959)	745	23	1	63	2	215	2			167	1
<i>Cryptopygus ponticus</i> (Stach, 1947)										6	
<i>Folsomides navacerradensis</i> Selga, 1962		19		3							
<i>Folsomides xerophilus</i> Fjellberg, 1993	97										
<i>Folsomides pocosensillatus</i> Fjellberg, 1993	39										
<i>Entomobrya handschini</i> Stach, 1922	5						1				
<i>Lepidocyrtus tellecheae</i> Arbea & Jordana, 1990		8									
<i>Arrhopalites microphthalmus</i> Cassagnau & Delamare, 1953	2										
<i>Stenognathellus denisi</i> (Cassagnau, 1953)			4	6							

in Eucalyptus III and *Onychiurus penetrans*, found for the first time in our country, as well as *M. critica*, is exclusive of this site. *Mesaphorura* sp.2 and *Mesaphorura* sp.1 are probably endemic, the first to Portugal and the second to the Iberian Peninsula as well as *Microgastrura sensiliata* (Tab. II). Another group, also designated by Eucalyptus and appearing below the Barrocal 94 group (composed of *Protaphorura armata*, *Proisotoma coeca* and *Tetracanthella hygropetrica*) comprises species only appearing in this biotope. Only *Proisotoma coeca*, an endemic to Portugal, is exclusive of Eucalyptus I and *Tetracanthella hygropetrica* is the dominant species represented also in Eucalyptus I by 57 individuals.

The fourth sub-group (composed of *Onychiurus circulans*, *Arrhopalites elegans*, *Paratullbergia callipygos* and *Stenognathellus denisi*) is also mainly represented in Quercus sites, with exclusive species of these biotopes. The most representative species of this group, *Stenognathellus denisi*, has not yet been referred for Portuguese fauna (Tab. III).

The twelve taxa of the following sub-cluster (the fifth) show a marked preference for Rhododendron. Only the first three species (*Microgastrura minutissima*, *Arrhopalites furcatus* and *Oncopodura crassicornis*) are also occurring in Sagres and Barrocal 96. *Lepidocyrtus paradoxus*, *Willowsia* sp., *Pogonognathellus flavescens*, *Sminthurus* cf. *multipunctatus* and the Iberian endemic, *Lepidocyrtus tellecheae*, are exclusive of this biotope and *Oncopodura crassicornis*, *Xenylla schillei*, *Fissuraphorura gisini* and *Tomocerus vulgaris* are equally represented in Q. canariensis but in low numbers. *Willemia intermedia* was also found in Eucalyptus III. *Fissuraphorura gisini*, *Microgastrura minutissima* and *Lepidocyrtus tellecheae* are reported for the first time to Portuguese fauna (Tab. III); this species, which was recently described, presents a distribution ranging from Navarra to Algarve.

The last subgroup of Serra de Monchique cluster includes nine taxa, from which four (*Cryptopygus*

sphagneticola, *Entomobrya albocincta*, *Lepidocyrtus lanuginosus* and *Pseudosinella* sp.) appear exclusively in Q. canariensis. Among the other taxa of this subgroup *Neelus murinus* also occurs in salt-marshes and *Caprainea bremondi* in Pinewood II and Barrocal 96.

The cluster designed by Barrocal 96 includes twenty one taxa that appeared exclusively or preferentially in this biotope located between Alte and Salir. Among the eight exclusive species we can emphasise *Metaphorura denisi*, the dominant species represented by 266 specimens, *Friesea stachi*, *Willowsia* sp., probably endemic, and *Troglopedetes* cf. *cavernicola*. This species has a special interest because it is an endemic species known, until now, exclusively from caves in the South of Portugal (Tab. II). According to DEHARVENG (personal communication) it must be considered as a paleoendemic dated from hotter periods of the Tertiary. *Metaphorura denisi* is recorded for the first time to Portugal and *Friesea stachi* to Iberian Peninsula. *Gamachorutes verrucosus*, also found in Pinewood I, is a very interesting Iberian endemic species, which appears for the first time after its original description in 1978, based in individuals from Algarve, Malaga and Cordoba.²

Among the nine taxa forming the cluster named Barrocal 94, located in Carvoeiro, near Farol de Alfanzina, *Stenacidia hystrix* is, among the six exclusive species of this site, an interesting and rare mediterranean species.

All nine taxa belonging to the cluster Pinewood II are exclusive of this biotope. *Cryptopygus ponticus* is referred for the first time to our country (Tab. III) and *Proisotoma gisini* is an endemic species to Portugal (Tab. II). The following cluster includes

² It is interesting to report that on preliminary sampling done in this site during 1994 (not included in this study) we found the species *Odontellina bisetosa*, an Iberian species found for the first time in our fauna.

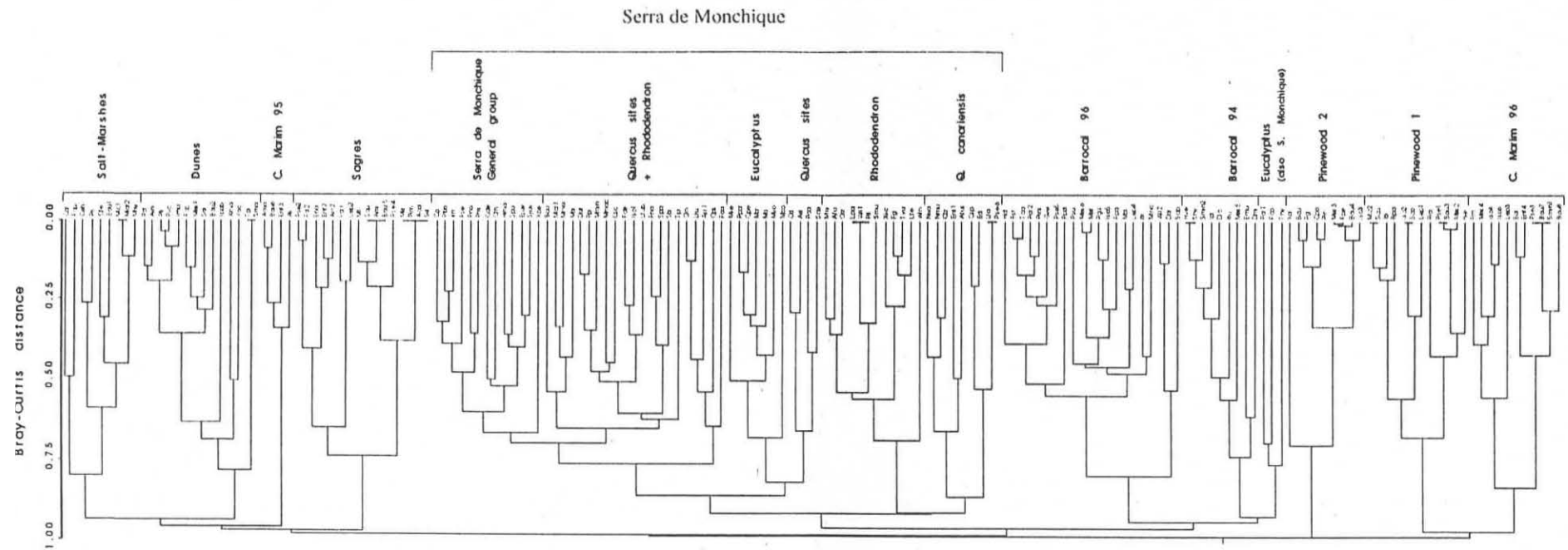


Fig. 4 – Diagram resulting from an agglomerative analysis (R mode) on the overall data matrix. Similarities were calculated over average abundances, based on Bray-Curtis coefficient

twelve taxa which appear in Pinewood I. the majority of them with exclusivity. Among these taxa, we can remark the presence of *Friesea ladeiroi*, known only from continental Portugal and Madeira island.

Most of the eleven taxa occurring in salt-marshes of C. Marim 1996 are not characteristic of this biotope. This fact may be explained by the rich and diverse vegetation cover in the Spring 1996, when we sampled (see study sites and sampling), leading to the appearance of species not characteristic of this biotope. Among these taxa we can denote a new species of *Pseudosinella* (Pse 3), probably endemic to Algarve (Tab. II).

CONCLUSIONS

The overall analysis of results reflects a distinguished separation of three groups of sites among the studied areas: the biotopes of Serra de Monchique, coastal "wet" biotopes (salt-marshes and dunes) and the other "dry" coastal or inland sites (Sagres, Pinewood and Barrocal sites).

This separation of different faunal spectra, well adapted to the different habitat types, enhances the importance of these areas in terms of biodiversity conservation; the number of new species referred for our fauna (Tab. III) and the number of rare or endemic species (Tab. II) helps in this goal.

It is difficult to grade the different areas in terms of conservation, since each one of them supports a great variety of Collembola species and also interesting species from other invertebrate groups and plants. Even so, we would like to highlight the Serra de Monchique area, specially those biotopes dominated by *Rhododendron ponticum baeticum*, a relictual endemic shrub, occurring in Portugal only in this mountain and in the mountain of Caramulo and also the biotope dominated by *Quercus canariensis*, which presents equally a very restricted occurrence both in Portugal and in Spain. being Serra de Monchique its exclusive area in our

country (ROCHA AFONSO, 1991). If we look at the presence of endemic species (Tab. II) we could see that they were concentrated in this mountain, reinforcing this position.

All these five areas are constantly being threatened by several stress factors such as reafforestation with exotic species (here, Eucalyptus is a critical problem in Serra de Monchique), forest fires and by uncontrolled touristic development (a serious threat in coastal areas). In face of this situation, well established conservation plans are needed to avoid habitat degradation, which is the major threat to biological diversity (PRIMACK, 1993). It makes no sense to preserve habitats without looking and protecting those species living there. Seen most of the times as different perspectives, habitat and species conservation must be requirements acting mutually in a well balanced conservation plan.

Reinforcing the idea that endemic or rare biota represent, from a conservation perspective, the most valuable and vulnerable element of the fauna, implies that high endemism areas should therefore be considered a priority for conservation (DEHARVENG, 1996). It is our goal to make the data from this study available both to the scientific community and to the competent authorities dealing with nature conservation in Portugal; recommendations will be made to preserve or restore the biological richness of these areas, encouraging the adoption of protective measures and the creation of research plans, without neglecting the necessity to continue the systematic inventory of them. In fact, while certain conspicuous groups, such as phanerogames, mammals and birds, are reasonably well known to science, other groups, such as insects, have not been thoroughly studied. So, there is a vital need for more taxonomic scientists to study, classify, map and protect the great biological diversity of this group, which contains a considerable portion of all known animal species of a

certain area and also plays a major role in ecosystem function (PRIMACK, 1993).

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